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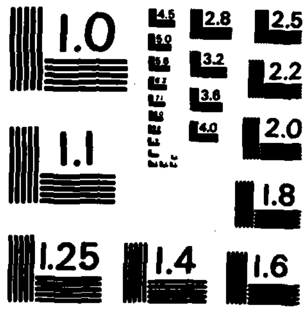
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by

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THE ROLE OF BOUND WATER IN THE ELECTRO-RHEOLOGICAL EFFECT

(PRO ROL' ZV'YAZANOI VODI V ELEKTROREOLOGICHNOMU EFEKTI)

by

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EDITOR'S SUMMARY

Using a 25% suspension of potato starch in vaseline oil, the authors have studied the dependence of the electro-rheological effect upon hydration level of the disperse phase.

It is shown that as the moisture content of the disperse phase is increased, the electro-rheological effect passes through a maximum. As the electrical field intensity is increased, the positions of such maxima shift towards lower moisture levels. The I/V characteristic is non-linear.

It is to be noted that the electro-rheological maxima are attained at moisture contents consistent with the water being in a bound state.

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Under the effect of strong electrical fields it is possible to observe a rapid and reversible increase in the viscosity of non-aqueous dispersions - the electro-rheological (ER) effect[1-3]. One can consider this to be a manifestation of structure formation as the result of the polarisation of and the interaction between particles of the disperse phase. In systems with a hydrophilic dispersed phase, a decisive role in structure formation is played by water absorbed on the surface of the particles[3].

This Paper describes the results of an investigation into the dependence of the ER-effect upon the interaction characteristics of the disperse phase with water.

Potato starch, a typical highly hydrophilic natural polymer, was the subject of the investigation. It was carefully washed free from electrolytes, dried at 60^{o} for 6 h and then at 110^{o} until constant weight was reached. It was moistened under vacuum and left for 4 days. Moisture content was determined gravimetrically.

The ER characteristics of the suspension of starch in vaseline oil were investigated in a rotary plastoviscometer-condenser, with a radial gap between electrodes of 0.5 mm[4]. The maximum shear stress at a velocity gradient of 30 s^{-1} was recorded before and after the application of the electric field.

Fig 1 shows the effect of hydration on the rheological behaviour of the suspension at various field strengths.

For suspensions of dry starch (W = 0%) the application of an electric field has practically no effect on the shear stress. Hydration of the disperse phase, however, sharply changes the picture: as moisture levels rise, the differential shear stress, $\Delta\tau$, increases, attains a maximum and then falls. The threshold value of the moisture for which the ER effects becomes apparent, decreases with increase in the field intensity. A particularly interesting feature is the displacement of the maxima in the $\tau(W)$ curves towards lower moisture content in the disperse phase, as the electric field increases. Also, the higher the field the more sharp are the maxima. However for moisture content below 20% the growth and displacement of the maxima are barely observable at high fields; that is to say, a saturation effect is apparent.

This is manifest in the fact that $\Delta\tau$ attains maximum values for moisture levels in the starch which do not exceed the content of bound water (35%). On the basis of this observation one can advance some hypotheses. The change from a free to a bound state of water is accompanied by organisation of its structure. According to Dumanskii[5], the bonding of water on the surface of hydrophilic particles is achieved by hydrogen bond formation. Such bonds arise both between surface OH-groups and molecules of H_2O and between adsorbed molecules of water. Thus a chain structure of water molecules is formed on the surface, which enables the transfer of protons to take place in an electric field. This produces proton conduction and polarisation of the hydrophilic particles according to Maxwell-Wagner[8]. Bound water certainly possesses anisotropy of conductivity: the electrical conductivity measured tangentially to the surface of the adsorbent is higher than that normally[9,10]. Thus the electrical resistance is highest of all in the zones of contact between particles forming an inter-electrode structure. The voltage drop in

the inter-electrode space occurs basically in the contact regions. By virtue of this, the optimum conditions are created for polarisation interaction between particles in the disperse phase.

Besides polarisation interaction, the field effect may play an important role in structure formation: a strong electric field is generated in contact zones when chains of particles having weak conductivity are broken. This produces a strong electrostatic interaction of the structural elements and the considerable resistance of the chains is overcome[11]. With the appearance on the particle surface of free water (*ie* when moisture content of the starch exceeds 35%) collars of water are formed at contact sites and the electrical resistance falls sharply. This leads to a reduction in the polarisation interaction and to a weakening of the structure. A similar picture is observed when the electric field intensity increases. A rise in the conductivity is possible at the expense of breakdown and other effects in strong electric fields. However an increase in the conductivity of the system is accompanied by a reduction in its stability.

The current characteristics observed when an electric field is applied to the system under investigation, are shown in Fig 2.

For a field of 4 kV/cm the conductivity becomes perceptible when the moisture content reaches 30%. However for higher electric fields the current increases sharply for low moisture contents. The dependence of the conductivity on the field intensity has a strongly non-linear character which confirms the possibility of breakdown (the current magnitude corresponding to the maxima for various fields was limited to 60 μA).

Thus in hydrocarbon disperse systems containing hydrophilic particles, the ER-effect attains a maximum for moisture contents corresponding to bound water. A sharp increase in electrical conductivity with increase in the moisture content or in the electrical field intensity weakens the inter-electrode structure and reduces the ER-effect.

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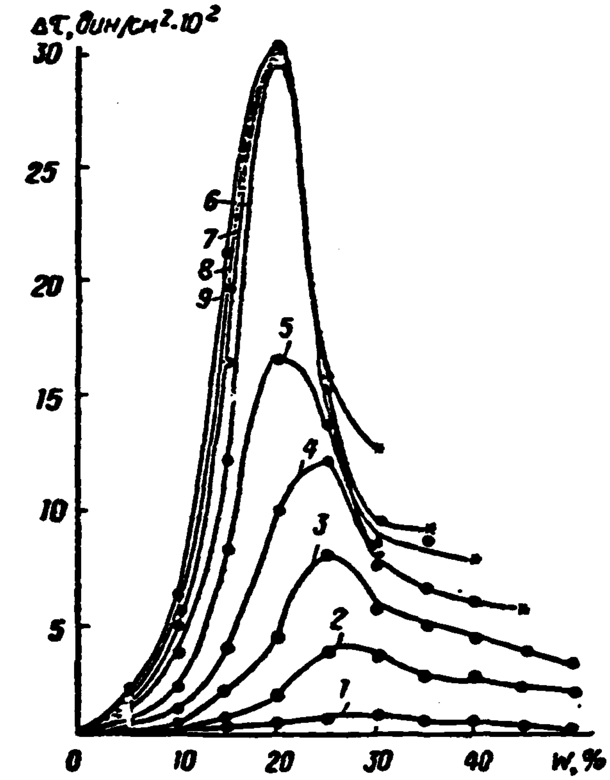
Fig 1



Key:
Ordinate = Δτ, dyne/cm^2 × 10^2

Fig 1 The dependence of a change in the differential shear stress Δτ, on the moisture content, w.%, of a disperse phase, in a 25% suspension of starch in vaseline oil for various electrical field intensities (in kV/cm):
1 - 4; 2 - 8; 3 - 12; 4 - 16; 5 - 20; 6 - 24; 7 - 28; 8 - 32; 9 - 36; * - breakdown.

Fig 2

Fig 2 The dependence of the current (J mA) in a 25% suspension of starch in vaseline oil, on the moisture content, w.%, of the disperse phase for various electrical field intensities (in kV/cm):

1 - 4; 2 - 8; 3 - 12; 4 - 16; 5 - 20; 6 - 24; 7 - 28; 8 - 32.

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